SESSION V: Optoelectronic Technology and Applications

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WPM 5.1: Integrated Electronics for a Reading Aid for the Blind†

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A NOVEL OPTICAL-TACTILE READING AID which allows a blind person immediate access to virtually all printed material used by sighted people has been developed. It occupies a volume approximately equal to that of an ordinary desk-size dictionary. Its singular features are a direct result of the application of integrated electronics.

The principle of operation of this direct translation reading aid[1] is illustrated by Figure 1. The bottom plane of the figure represents a printed character (A) of an ordinary book, magazine or newspaper. A simple optical system is used to focus an image of the character on an array of phototransistors represented by the middle plane of Figure 1. The output signals of the phototransistors are detected and processed to provide the control voltages for a rectangular matrix of closely-spaced piezoelectric tactile stimulators or bimorphs, which are arranged in one-to-one correspondence with the elements of the photosensor array. The tips of a pattern of vibrating bimorphs extend slightly through perforations in a plastic plate represented by the top plane of Figure 1. By placing an index finger on the plastic plate, a reader can sense the directly-translated tactile facsimile of a printed character whose optical image is focused on the phototransistor array.

A schematic diagram of one of 144 identical parallel channels of a rudimentary model[2] of the reading aid is illustrated in Figure 2. An array of discrete phototransistors operating in the integration mode is illuminated by a coherent bundle of optical fibers. When an illuminated transistor is sampled it turns on the left side of an asymmetric flip-flop which in turn causes the output inverter transistor to short-circuit the bimorph. A dark phototransistor, corresponding to an inked portion of a printed character, turns off the inverter transistor thereby energizing the associated bimorph and stimulating the finger of the reader.

The design innovations of the multiplex model of the reading aid illustrated in Figure 3 produce major performance improvements and reduce hardware compared with the parallel-channel model. A common multiplexing shift register is used for interrogation of the phototransistor array and control of the bimorph array. The asymmetry of the 24×6 phototransistor array is exploited by using one-dimensional y multiplexing to reduce hardware, improve sensitivity by reducing switching noise and diminish phototransistor and comparator nonuniformity problems via a six-times longer sample time compared with x-y multiplexing. Temporary memory of a phototransistor's previous output during its integration time, provided by 144 flip-flops in the parallel channel system, is accomplished using the self-capacitance of its associated bimorph. The logical AND required to control a given bimorph is performed by its corresponding driver transistor. Six comparatively well-matched, sensitive high-quality comparators (C), which replace 144 flip-flops, improve circuit uniformity and sensitivity by more than ten times, thus enhancing reading speed and accuracy while increasing potential battery life.

Markedly improved convenience and flexibility result from the addition of an automatic threshold control (ATC) to the reading aid; Figure 4. By sensing the maximum output voltage of the phototransistor array and automatically setting the comparator reference voltage at a fraction of this value, the ATC frees the reader from all adjustments as he changes from dull to glossy paper and enhances accuracy for poor contrast ratios compared with a manual threshold control. Alternatively, maximum array output can be controlled using feedback to the light source. A four-level grey-scale tactile facsimile can be achieved by automatically setting the comparator reference voltage at a different fraction of array maximum output voltage for each of four successive frame periods.

A monolithic imaging array improves sensor uniformity and reduces hand-held reading unit size compared with a discrete phototransistor array requiring optical fibers. These improvements enhance reading accuracy and speed, as well as reduce reader fatigue. The order of the (24×6) monolithic array and its aspect ratio (2:1) are determined by printed character dimensions, short-term human memory, bimorph size and index finger dimensions. Array cell area ($\sim 5 \times 10$ mils) is optimized for maximum responsivity, small reading head size and high fabrication yields. Harmful intercellular crosstalk is virtually eliminated by designing for phototransistor $h_{FE} \geq 200$ and $C_{TC} / C_{TE} \geq 5$ as well as a limited output voltage. A maximum light-to-dark contrast ratio for the array is achieved by optimizing SiO_2 thickness, collector junction depth ($\sim 2\mu$) and substrate junction depth ($\sim 8\mu$) for maximum visible and minimum IR response[3].

Reading speeds greater than twenty words per minute have been achieved by subjects with rather limited experience using laboratory models (Figure 5) of this optical-tactile reading aid. Further increases in reading speed are anticipated. It appears quite reasonable that such a reading aid could become widely used among the blind.

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[1]Linvill, J. G., and Bliss, J. C., "A Direct Translation Reading Aid for the Blind", *Proc. IEEE*, p. 40-51; Jan., 1966.

[2]Joy, R. C., and Linvill, J. G., "Optoelectronic Circuitry for a Reading Aid", *IEEE Journal of Solid-State Circuits*, Vol. 3, No. 4; Dec., 1968.

[3]Gary, P. A., and Linvill, J. G., "A Planar Silicon Photosensor with an Optimal Spectral Response for Detecting Printed Material", *IEEE Trans. on Electron Devices*, p. 30-39; Jan., 1968.

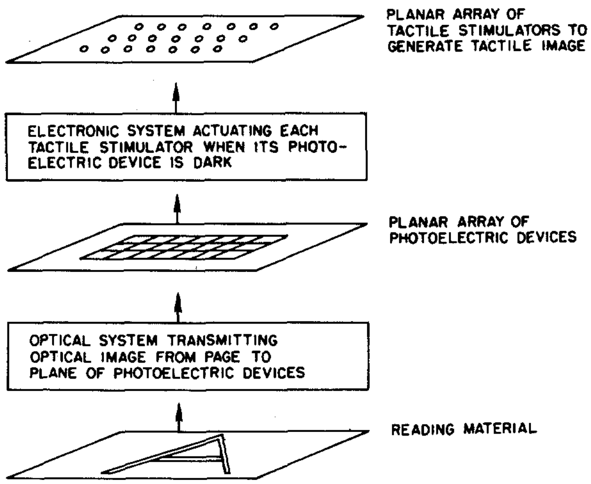

FIGURE 1—**Schematic representation of principle of operation of the reading aid.**

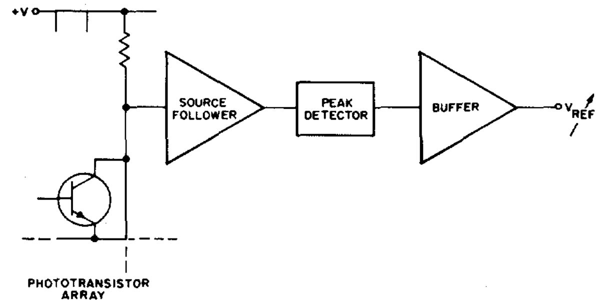

FIGURE 4—**Simplified block diagram of automatic threshold control (*ATC*).**

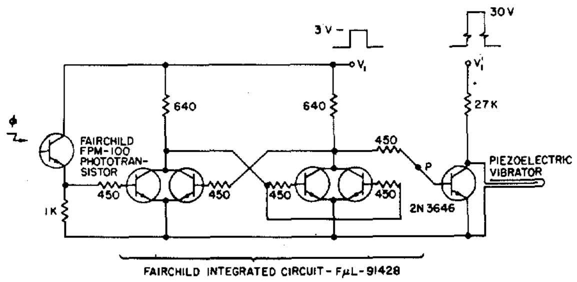

FIGURE 2—**Circuit diagram of one channel of the parallel channel model.**

FIGURE 5—**Model of reading aid showing reading unit guided by right hand of operator, multiplex electronics beneath tracking aid, tactile unit at left of operator and light box.**

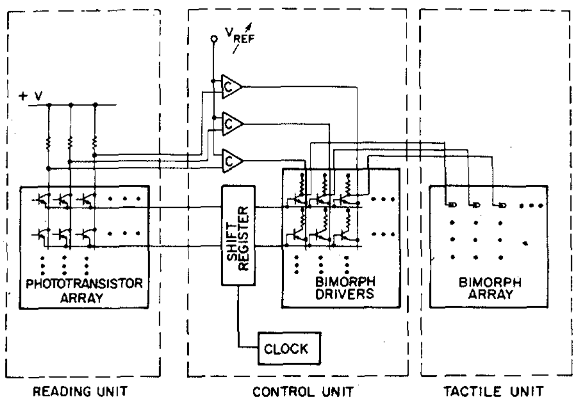

FIGURE 3—**Simplified block diagram of multiplex model.**